PATENT
2879 (203-3439)

ELECTROSURGICAL ELECTRODE HAVING A NON-CONDUCTIVE POROUS CERAMIC COATING

CROSS REFERENCE TO RELATED APPLICATIONS:

This application claims the benefit of priority to U.S. Provisional Application Serial No. 60/432,385 filed on December 10, 2002, the entire contents of which are hereby incorporated by reference herein.

BACKGROUND

1. Technical Field

The present disclosure is directed to electrosurgery and, in particular, to an electrosurgical electrode having a non-conductive porous ceramic coating for controlling the amount of current per arc.

2. Description of the Related Art

Tissue heating is proportional to the square of the amount of current being generated through the tissue and tissue vaporization is, in turn, generally proportional to current. Vaporization of tissue is proportional to the amount of energy in the arc. This energy, in combination with the Cathode Fall Voltage, derives the power for vaporization. Thermal spread is dependent on the amount of heat generated within the tissue and is dependent on tissue resistivity and the arc energy squared. As can be appreciated, by not controlling the thermal spread the depth of ablation is difficult to predict and control.

Therefore, during electrosurgery, an increase or decrease in the amount of current provides a different tissue effect. This phenomenon is due to a variable referred to as the crest factor (CF). The crest factor can be calculated using

the formula: $CF=V_{PEAK}/V_{RMS}$, where V_{PEAK} is the positive peak of the waveform and V_{RMS} is the RMS value of the waveform. The crest factor can also be calculated using the formula: $CF=[(1-D)/D]^{1/2}$, where D is the duty cycle of the waveform and is defined as $D=T_1 / (T_1 + T_2)$.

Based on the above formulas, it is evident that when operating an electrosurgical generator system in either the "cut", "blend" or "coagulate" mode, the range of the crest factor varies from one mode to another. For example, the "cutting" mode typically entails generating an uninterrupted sinusoidal waveform in the frequency range of 100kHz to 4MHz with a crest factor in the range of 1.4 to 2.0. The "blend" mode typically entails generating an uninterrupted cut waveform with a duty cycle in the range of 25% to 75% and a crest factor in the range of 2.0 to 5.0. The "coagulate" mode typically entails generating an uninterrupted waveform with a duty cycle of approximately 10% or less and a crest factor in the range of 5.0 to 12.0. For the purposes herein, "coagulation" is defined as a process of desiccating tissue wherein the tissue cells are ruptured and dried. "Vessel sealing" is defined as the process of liquefying the collagen in the tissue so that it reforms into a fused mass with significantly-reduced demarcation between the opposing tissue structures (opposing walls of the lumen). Coagulation of small vessels is usually sufficient to permanently close them. Larger vessels need to be sealed to assure permanent closure.

An increase in the crest factor results in more current per arc at a given power setting. Further, since tissue heating is proportional to the amount of current through the tissue squared and tissue vaporization is proportional to the amount of

current being generated through the tissue, a doubling of current per arc results in four times as much tissue heating and twice the amount of tissue vaporization when an electrode connected to the electrosurgical generator system contacts the tissue. Known electrodes cannot control or limit the current per arc to achieve a particular surgical effect, e.g., a fine cut. Accordingly, such electrodes do not have the ability to manipulate or control the proportion of tissue vaporization to tissue heating, in order to achieve more controllable and desirable surgical effects.

Therefore, it is an aspect of the present disclosure to provide an electrosurgical electrode capable of controlling or limiting the current per arc for controlling the both tissue heating and tissue vaporization.

SUMMARY

An electrosurgical electrode and electrosurgical generator system capable of controlling or limiting the current per arc in real-time during an electrosurgical procedure is disclosed. The conductive electrosurgical electrode is configured for being connected to an electrosurgical generator system and has a non-conductive, porous ceramic coating that "pinches" or splits the arc current generated by the electrosurgical generator system into a small diameter channel, effectively keeping the same current and voltage, but creating several small arcs from one large arc.

This has the effect of separating the arc current, effectively increasing the current frequency, resulting in a finer cut or other surgical effect. That is, the

non-conductive, porous ceramic coating enables the application of a low frequency current to achieve surgical results indicative of a high frequency current, while minimizing or preventing thermal damage to adjacent tissue.

The number of small arcs created from one large arc is inversely proportional to the diameter of the pores in the ceramic coating. Preferably, the diameter of each pore is less than the diameter of the arc. Hence, when electrosurgical current is applied to the electrosurgical electrode, the arc current is split between the pores in the electrode, thereby, controlling or limiting the arc current through each pore. This effect which controls or limits the arc current through each pore is referred to as MicroHollow Cathode Discharge (MCD or MHCD).

The diameter of each pore can vary from the diameter of other pores to produce different surgical effects when operating the electrosurgical generator system in one of several modes, such as cut, blend and coagulation modes. In either embodiment, MCD enables the surgeon to control the proportion of tissue vaporization to tissue heating, in order to achieve more controllable and desirable surgical effects.

The number of pores per square centimeter controls the arc area. As the number of pores per square centimeter increases, the arc area decreases, and vice versa. A large arc area is desired when operating the electrosurgical generator system in the coagulation mode and a small arc area is desired when operating in the cut mode. The thickness of the non-conductive, porous ceramic coating controls

the system resistance and voltage needed to establish the arc. The thicker the coating the greater the system resistance and voltage needed to establish the arc, and vice versa.

Alternative embodiments provide for the non-conductive, porous ceramic coating to be applied to roller-ball type electrodes for improving the arc distribution across the tissue, and hence, the efficiency of the electrode, as compared to roller-ball type electrodes not coated with the non-conductive, porous ceramic material. Other embodiments and features include modifying the geometry of the electrode before applying the non-conductive, porous ceramic coating on the electrode, so as to control where the arc is split and/or cutting/coagulating occurs, i.e., along edge of the electrode, along length of the electrode, across width of the electrode, etc.

Further, the electrode can be coated accordingly to provide an electrode having at least a portion thereof configured for cutting tissue, at least a portion thereof configured for coagulating tissue, etc. Further still, the pore diameter, the pore length, and/or pore pattern can be varied to produce different effect to control cutting and coagulating tissue.

One embodiment of the present disclosure provides an electrode assembly for controlling the electrosurgical arc current from an electrosurgical generator. The electrode assembly includes an electrode having a conductive surface connected to a source of electrosurgical energy. The assembly further includes a non-conductive, porous ceramic material substantially coating the

conductive electrode. The coating has a thickness and includes a plurality of pores dispersed therein having a diameter. Upon actuation of the electrosurgical generator, electrosurgical energy from the electrosurgical generator creates an initial arc current across the conductive surface of the electrode. The initial arc current has a diameter greater than the diameter of the pore such that the initial arc current is forced to split into a plurality of subsequent arc currents having a diameter smaller than the diameter of the initial arc current in order to conduct electrosurgical energy through the pores of the non-conductive, porous ceramic material.

The present disclosure also provides a method for controlling the amount of electrosurgical energy to tissue. The method includes the steps of providing an electrode having a conductive surface connected to a source of electrosurgical energy, and coating the electrode with a non-conductive, porous ceramic material having a thickness and a plurality of pores dispersed therein each having a diameter. The method further includes the step of activating the electrosurgical energy source to create an initial arc current across the conductive surface of the electrode. The initial arc has a diameter greater than the diameter of the pores such that the initial arc current is forced to split into a plurality of subsequent arc currents having a smaller elevator than the diameter of the initial arc current in order to conduct electrosurgical energy through the pores of the non-conductive, porous ceramic coating.

Further features of the above embodiments will become more readily apparent to those skilled in the art from the following detailed description of the apparatus taken in conjunction with the drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

Various embodiments will be described herein below with reference to the drawings wherein:

FIG. 1 is an enlarged, cross-sectional view of a portion of a conductive electrode coated with a non-conductive, porous ceramic coating in accordance with the present disclosure;

FIG. 2 is an enlarged, cross-sectional view of a conductive electrode coated with a non-conductive, porous ceramic coating having varying pore diameters, varying pore lengths, and varying number of pores per square centimeter in accordance with the present disclosure;

FIG. 3 is an enlarged, cross-sectional view of a conductive electrode coated with a non-conductive, porous ceramic coating with various thicknesses in accordance with the present disclosure;

FIG. 4 is an enlarged, cross-sectional view of a roller-ball type, conductive electrode coated with a non-conductive, porous ceramic coating in accordance with the present disclosure; and

FIG. 5 is an enlarged, cross-sectional view of a conductive electrode having a modified geometry and coated with a non-conductive, porous ceramic coating in accordance with the present disclosure.

DETAILED DESCRIPTION

Reference should be made to the drawings where like reference numerals refer to similar elements. Referring to FIG. 1, there is shown an enlarged, cross-sectional view of one embodiment of a conductive electrode according to the present disclosure. The electrode is designated generally by reference numeral 100 and it is connected to an electrosurgical generator system 102. The electrode 100 is coated with a non-conductive, porous ceramic coating 104 which "pinches" or splits the arc current generated by the electrosurgical generator system 102 into a small diameter channel, effectively keeping the same current and voltage, but creating several small arcs from one large arc.

This has the effect of separating the arc current, effectively increasing the current effect to the tissue, resulting in a finer cut or other surgical effect. That is, the non-conductive, porous ceramic coating 104 enables a low frequency current to achieve surgical results indicative of a high frequency current, while minimizing or preventing thermal damage to adjacent tissue.

The coating 104 includes a plurality of pores 106 having a uniform diameter "D" in the range of 10μm to 1000μm and a uniform length "L" (100 to 500 micrometers). The number of small arcs created from one large arc is inversely proportional to the diameter "D" of the pores 106 in the ceramic coating 104. Preferably, the diameter "D" of each pore 106 is less than the diameter of the arc. Hence, when electrosurgical current is applied to the electrosurgical electrode 100, the arc current is split between the pores 106 in the electrode 100, thereby,

controlling or limiting the arc current through each pore 106. This effect which controls or limits the arc current through each pore 106 is referred to as "MicroHollow Cathode Discharge" (MCD or MHCD).

As shown by FIG. 2, it is envisioned that the diameter "D" and the length "L" of the plurality of pores 106 can vary in size to produce different surgical effects when operating the electrosurgical generator system 102 in one of several modes, such as cut, blend and coagulation modes. In either embodiment, MCD enables the surgeon to control the proportion of tissue vaporization to tissue heating, in order to achieve more controllable and desirable surgical effects.

Additionally, as shown by FIG. 2, the number of pores per square centimeter (or the pattern of the pores 106) can be uniform (as shown by FIG. 1) or vary along the length of the electrode 100. The number of pores per square centimeter controls the arc area. As the number of pores per square centimeter increases, the arc area decreases, and vice versa. A large arc area is desired when operating the electrosurgical generator system 102 in the coagulation mode and a small arc area is desired when operating in the cut mode.

The thickness of the non-conductive, porous ceramic coating 104 controls the system resistance and voltage needed to establish the arc. The thicker the coating 104 the greater the system resistance and voltage needed to establish the arc, and vice versa. With continued reference to FIG. 1, the coating 104 has a thickness "T" which is predetermined during fabrication of the electrode 100 for effectively operating the electrode 100 in one of several modes, such as cut,

coagulate and blend, by using the electrosurgical generator system 102. A small thickness for the coating 104 in the range of 10μm to 500μm is preferred for operating the electrode 100 in the "cut" mode; a medium thickness in the range of 250μm to 1mm is preferred for operating the electrode 100 in the "blend" mode; and a large thickness in the range of 500μm to 2mm is preferred for operating the electrode 100 in the "coagulate" mode.

As shown by FIG. 3, the thickness "T" of the coating 104 can vary at one portion 108 of the electrode 300 with another portion 110 of the electrode 300, in order to be able to effectively operate the electrode 300 in more than one mode by using the electrosurgical generator system 102. The electrode 300 shown by FIG. 3 has two portions 108a, 108b for effectively operating the electrode 300 in the coagulate mode, and one portion 110 for effectively operating the electrode 300 in the cut mode.

It is envisioned that the two opposing jaw members may be created with coating 104 in this manner to simultaneously effect tissue sealing between two opposing 108a portions and 108b portions of each jaw member and effect tissue cutting between two opposing 110 portions. More particularly, the thicker coating areas 108a and 108b on each jaw member will tend to coagulate tissue held there between while the thin coating area 110 will tend to cut tissue held therebetween. As can be appreciated, it is envisioned that a single energy activation may yield a dual tissue effect which greatly simplifies sealing and dividing tissue.

With reference to FIG. 4, there is shown an enlarged, cross-sectional view of a roller-ball type electrode 400 coated with the non-conductive, porous ceramic coating 104 in accordance with the present disclosure. The coating 104 for this type of electrode improves the arc distribution across the tissue, and hence, the efficiency of the electrode 400, as compared to roller-ball type electrodes not coated with the non-conductive, porous ceramic material.

With reference to FIG. 5, there is shown an enlarged, cross-sectional view of an electrode 500 having a modified geometry and coated with the non-conductive, porous ceramic coating 104 in accordance with the present disclosure. The geometrical configuration of the electrode 500 enables control of where the arc is split and/or cutting/coagulating occurs, e.g., along edge of the electrode 500, along the length of electrode 500, across the width of electrode 500, etc. Various diameters, lengths, and patterns (number of pores per square centimeter) for the pores 106 are contemplated besides uniform diameter, length and uniform distribution. Also, a varying or uniform thickness for the coating 104 is contemplated.

The method of the present disclosure includes the steps of providing an electrode having a conductive surface connected to a source of electrosurgical energy, and coating the electrode with a non-conductive, porous ceramic material having a thickness and a plurality of pores dispersed therein each having a diameter. The method further includes the step of activating the electrosurgical energy source to create an initial arc current across the conductive surface of the electrode. The initial arc has a diameter greater than the diameter of the pores such

that the initial arc current is forced to split into a plurality of subsequent arc currents having a smaller elevator than the diameter of the initial arc current in order to conduct electrosurgical energy through the pores of the non-conductive, porous ceramic coating.

From the foregoing and with reference to the various figure drawings, those skilled in the art will appreciate that certain modifications can also be made to the present disclosure without departing from the scope of the same. For example, it is envisioned that the pore diameter of the coating 104 may be varied during the manufacturing process according to the type of instrument being used. For example, one size pore diameter may be used for electrosurgical blades for coagulating or cutting tissue which another pore diameter may be used for electrosurgical forceps which utilized a combination of closing force, gap distance between jaw members and electrosurgical energy, to seal tissue. Moreover, it is envisioned that the number of pores per inch may be modified during the manufacturing process to control the arc area and adverse collateral effect to surrounding tissue. It is also contemplated that the thickness of the coating may be modified during manufacturing to establish a preferred resistance and voltage for creating the arc.

Although this disclosure has been described with respect to preferred embodiments, it will be readily apparent to those having ordinary skill in the art to which it appertains that changes and modifications may be made thereto without departing from the spirit or scope of the disclosure.